ARTICLE TRANSFER SYSTEM

FIELD OF THE INVENTION

This invention relates to an article transfer system, particularly useful in applications where precise positioning of an article with respect to a processing or metrology tool is required.

BACKGROUND OF THE INVENTION

Various applications, such as article inspection and measurements, as well as lithography processing, require precise movement of the article with respect to a processing tool along a vertical axis (Z-axis). For example, in the manufacture of semiconductor devices, as well as testing of circuits on semiconductor wafers, the wafer is typically supported on a stage mounted for a Z-axis movement (Z-stage) and sometimes also for rotation (Z/Theta stage).

U.S. 5,150,040 discloses a dual mode Z/Theta stage for supporting and moving a workpiece, such as a semiconductor wafer, for positioning during testing. The Z/Theta stage has a peripheral four-point elevator drive. The elevating suspension comprises parallel, vertically oriented, rigid lift pins, which bear the weight of a top-plate. The lift pins are located about the periphery of the stage to provide stability of the support. The top plate essentially floats on the lift pins so that virtually no frictional forces are translated to lift pins. The lift pins are elevated together by the force of four matched pin lift levers, crank arms. The crank arms are driven by downward force from a vertically translating air piston, which is in contact with the crank arms. The air piston provides a gentle force moderated by pneumatic pressure, which can moderate the full force of a stepping motor that drives it.

SUMMARY OF THE INVENTION

There is a need in the art to facilitate processing of articles by supporting an article on an article transfer system enabling precise movement of the article along a vertical axis. Here, the term *"processing"* signifies also measurement or inspection of articles.

The system of the present invention has a simple construction allowing precise movement of an article along a vertical axis (Z-axis) within a limited range of distances, and preferably also rotation of the article about the Z-axis.

The main idea of the present invention consists of utilizing a spring suspension arrangement for supporting an article-carrying member. The spring suspension arrangement is formed by two assemblies arranged in a coaxial relationship, one inside the other, wherein the outer assembly is configured to define two spaced-apart parallel planes perpendicular to the vertical axis. The arrangement is such that the first assembly is kept at a fixed position, and the second assembly, which is intended for supporting an article-carrying member, is driven for movement along a vertical axis with respect to the first assembly, while the assemblies are attached to each other by first and second membrane-like members arranged in a spaced-apart parallel relationship along the vertical axis. The vertical movement of the second assembly causes the deformation of the membrane-like members, thereby limiting the movement of the second assembly (and consequently the article-carrying member) by the deformability of membranes.

Thus, according to a broad aspect of the present invention, there is provided a system for controlling an axial movement of an article, the system comprising:

- a support stage assembly;
- a spring suspension arrangement mounted on said support stage assembly and comprising first and second assemblies arranged in a coaxial relationship one inside the other, the first assembly being attached to said support stage assembly and the second assembly serving for supporting an article-carrying member and being driven for movement along said axis

with respect to the first assembly, the outer one of the first and second assemblies being configured to define two spaced-apart parallel planes perpendicular to said axis, said first and second assemblies being attached to each other by first and second membrane-like members arranged in a spaced-apart parallel relationship along said axis.

According to one embodiment of the invention, the outer assembly is composed of at least three spaced-apart pin-like members kept at a fixed position with respect to one another, and the inner assembly is composed of at least one pin-like member. According to another preferred embodiment of the invention, the outer and inner assemblies are configured as cylinders or prisms, of preferably substantially the same height. The inner assembly at its top and bottom is attached to the top and bottom of the outer assembly by said first and second membrane-like members, respectively. The membrane-like members are preferably of annular geometry, and may be clamped to the opposite sides of each of the outer and inner assemblies via clamping rings.

According to another aspect of the invention, there is provided a system for controlling movement of an article along at least a vertical axis, the system comprising:

- a support stage assembly;
- a spring suspension arrangement mounted on said support stage assembly and comprising first and second vertically oriented cylindrical assemblies arranged in a coaxial relationship one inside the other, the first assembly being attached to said support stage assembly and the second assembly serving for supporting an article-carrying member and being driven for movement along the vertical axis with respect to the first assembly, the inner cylindrical assembly at its top and bottom being attached to the top and bottom of the outer cylindrical assembly by, respectively, first and second membrane-like members thereby arranged in a spaced-apart parallel relationship along the vertical axis.

According to yet another aspect of the invention, there is provided a system for controlling movement of an article along at least a vertical axis, the system comprising:

- a support stage assembly;
- a spring suspension arrangement mounted on said support stage assembly and comprising first and second vertically oriented cylindrical assemblies arranged in a coaxial relationship one inside the other, the outer cylindrical assembly being attached to said support stage assembly and the inner cylindrical assembly serving for supporting an article-carrying member and being driven for movement along the vertical axis with respect to the outer assembly, the inner cylindrical assembly at its top and bottom being attached to the top and bottom of the outer cylindrical assembly by, respectively, first and second membrane-like members being thereby arranged in a spaced-apart parallel relationship along the vertical axis,
- a drive assembly associated with said inner cylindrical assembly and operable to provide said movement thereof.

The article-carrying member mounted on the second assembly may be driven for rotation with respect to said second assembly in a plane perpendicular to said axis of movement of the second assembly. The support stage assembly may be driven for movement in a plane perpendicular to said axis of movement of the second assembly. Considering a disk-like article, the support stage assembly is preferably movable along at least one perpendicular axis for a distance of at least a radius of the article The system may thus be operable as a Z-Theta-stage, R-Z-Theta-stage or X-Y-Z-Theta-stage.

Thus, according to yet another aspects of the invention, there are provided an R-Theta-Z system and an X-Y-Theta-Z system for controlling movement of an article including the above-described spring suspension arrangement.

The system of the present invention has a simple (and low cost) construction, which can be operable by a simple servo-control mechanism and provides for smoothness of the article movement with high precision. These

features are of great importance for such applications as processing/inspection/measurements of semiconductor wafer structures. Generally, the system of the present invention can advantageously be used in optical measurements (precise focusing), electrical measurements (e.g., in four point probe measurements), near field measurements (e.g., eddy current based resistivity measurements), etc.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1A and 1B schematically illustrate the main constructional and operational principles of an article transfer and positioning system according to the invention;

Fig. 2 exemplifies a specific implementation of the system of the present the invention;

Fig. 3 more specifically illustrates a part of the system of Fig. 2 configured to provide rotation of an article supporting element about the Z-axis; and

Figs. 4A and 4B schematically illustrate the construction of a Z-R-Theta-system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides an article transfer and positioning system configured and operable to enable precise movement of the article along a vertical axis (Z-axis), and preferable also rotation about the Z-axis.

Figs. 1A and 1B schematically illustrate the main constructional and operational principles of a system **10** according to the invention. The system **10** includes such main constructional parts as a support stage assembly **12** and a spring

arrangement **11** mounted on the support stage assembly **12**. The stage **12** may be driven for movement in a horizontal plane, presenting the so-called X-Y-stage or alternatively R-Theta stage.

The spring arrangement **11** includes inner and outer assemblies **14A** and **14B**, wherein one of these assemblies - the outer assembly **14A** in the present example - is attached to the stage **12** and define upper and lower horizontal planes P_1 and P_2. The other assembly – inner assembly **14B** in the present example - is attached to the assembly **14A** in a manner to be vertically movable with respect to the assembly **14A** within a limited range of distances. This is achieved by attaching the assemblies **14A** and **14B** to each other via two membrane-like members M_1 and M_2. Thus, driving of the inner assembly **14B** for movement along the Z-axis would result in the simultaneous deformation of the membranes M_1 and M_2 (Fig. 1B), the limits of the Z-movement being defined by the deformability of the membranes and their dimensions. As shown in the figure in dashed lines, an article-carrying member **18** is mounted on the inner assembly **14B**, and would thus be movable together with the assembly **14B**. The membranes are preferably identical and are centered at the central axis **CA** of the inner assembly **14B**.

It should be understood that, alternatively, the same effect could be achieved by attaching the inner assembly **14B** to the stage **12**, rather than the outer assembly **14A**, and driving the outer assembly **14A** for movement along the Z-axis in a similar manner.

Driving of the inner assembly **14B** (or outer assembly, as the case may be) along the Z-axis can generally be achieved by associating this assembly with any suitable linear driver **20**.

It should also be understood that, generally, in order to define the upper and lower planes for the membranes' location (in their non-deformable position), the outer assembly **14A** can be formed by at least three spaced-apart members (e.g. rods or struts) N_1-N_3, preferably arranged so as to form a regular polygon (equilateral triangle in the present example) that are fixed to the stage **12** and are kept at a fixed position with respect to one another. As for the inner assembly, it

may be in the form of a member (e.g. rod-shaped) $\mathbf{N_4}$ located at the center of this polygon. Preferably, the assemblies **14A** and **14B** are configured as outer and inner prisms or cylinders.

Referring to **Fig. 2**, there is illustrated a specific, but non-limiting, example of implementation of a system **100** according to the invention for use in transferring and positioning of articles. The system **100** is configured as a Z-stage, and preferably also as an R-Theta-stage. The system **100** comprises a spring suspension arrangement **110** mounted on a stage assembly **112**. The stage **112** can be mounted for movement in a horizontal plane along one or two perpendicular axes (X-Y plane), i.e., presents an X-stage.

The spring arrangement **110** is formed by outer and inner cylinder-like assemblies (drums) **114A** and **114B**. The outer drum **114A** is formed with openings, generally at **115**, the provision of which is optional and is aimed at decreasing the weight of the entire construction and also at allowing access to the inner parts of the construction (e.g., for maintenance purposes). The drums **114A** and **114B** are attached to each other by top and bottom membrane-like members $\mathbf{M_1}$ and $\mathbf{M_2}$ (for example made of a stainless steel and having a thickness of 0.5 mm). The membranes M_1 and M_2 have an annular shape and are clamped to the drums by means of claiming rings **117A** and **117B**, respectively, and bolts **119A** and **119B**.

Further provided in the system **100** is a drive assembly **116** configured and operated for providing a movement of the drum **114B** along the Z-axis. In the present example, the drive assembly **116** comprises a mechanical pair formed by a roller bearing **116A** mounted on a central axis (shaft) **CA** of the inner drum **114B** and a wedge element **116B** supporting the bearing **116A** on its inclined surface. A linear motor **116C** is provided being connected to the wedge element **116B** for moving it along the X-axis. Thus, when the wedge **116A** is driven for a back and forward movement along the X-axis, the roller bearing **116B** drives the inner assembly **114B** for movement along the Z-axis. The inner drum **114B** serves for supporting an article holding assembly **118**. In the present example, where

measurements/inspection/processing of semiconductor wafers is considered, the wafer supporting assembly **118** includes a chuck unit **120** preferably mounted for rotation in the horizontal plane. Considering rotation of the chuck carrying a disk-like article (e.g., semiconductor wafer), the stage **112** is movable along the X-axis within the range defined by the radius of the article (of at least the wafer's radius). The system **100** thus presents the Z-R-Theta stage. It should be understood that, generally, the system **100** might utilize X-Y-movement of the stage **112** with and without a rotation of the chuck unit **120**.

Fig. 3, which is a cross-sectional view of a part of the system **100**, more specifically illustrates the chuck unit **120** mounted on the inner drum **114B**. As shown, the chuck unit **120** is mounted on a rotor-part **124A** of a motor **124**, whose stator-part **124B** is attached to the inner drum **114B**. As further shown in **Figs. 2** and **3**, the chuck unit **120** is mounted on a shaft of the rotor-part **124A** via a pair of spherical washers **125A** (male) and **125B** (female) facing each other by their concave and convex surfaces and a bolt **126**, e.g. spherical washers DIN 6319 commercially available from Ganter Griff. While mounting the chuck, its precise horizontal positioning can be regulated by displacing the washers with respect to each other.

Reference is now made to **Figs. 4A and 4B** showing the entire construction of the system **100** being used for supporting an article, e.g., wafer **W** (300mm diameter). The configuration of the system **100** presents an accurate R-Theta-Z-system that can be operable as an integrated or stand-alone wafer stage platform. In the present example, the system **100** is used for auto-focusing purposes to control the wafer's in-focus position relative to an optical measuring module located above the wafer (not shown).

Wafer **W** is hold by a buffer unit (frame) **130**. The construction and operation of the buffer unit **130** does not form a part of the present invention and therefore need not be specifically described. The preferred implementation of the buffer unit **130** is disclosed in co-pending U.S. application 10/232,384 assigned to the assignee of the present application. The buffer unit **130** is mounted on the stage

112 and associated with a drive mechanism (not shown) to be movable along the Z-axis with respect to the stage **112**, and consequently with respect to the chuck unit **120**, which is mounted on the inner drum **114B** of the spring suspension arrangement. The chuck **120** is typically provided with openings for vacuum holding of the wafer. Considering the use of such a buffer unit for gripping and holding a wafer (load/unload station), the diameter of the chuck **120** is smaller than the diameter of the wafer. The chuck **120** is movable along the Z-axis (due to the movement of the drum of spring suspension arrangement) within a 1mm-distance at a 0.1μm precision, and is 360-degree rotatable. In the present example, also mounted on the stage **112** is an optical system **132** serving as the so-called "notch finder" for identifying a wafer located on the chuck and/or providing angular positioning of the wafer with respect to a processing tool (measurement, inspection, etc. tool).

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as hereinbefore described without departing from its scope as defined in and by the appended claims.